RPL-TDR-64-109

R-5602

TOTAL IMPULSE MEASURING SYSTEM FOR SOLID-PROPELLANT ROCKET ENGINE

PHASE II REPORT

MARCH, 1964

SECOND PRINTING
AUGUST 1964

AIR FORCE ROCKET PROPULSION LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
EDWARDS, CALIFORNIA

PROJECT NO. 3850, TASK NO. 3850306

PREPARED UNDER CONTRACT NO. AF04 (611) - 8515

BY

V. C. PLANE

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A DIVISION OF NORTH AMERICAN AVIATION, INC.
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FOREWORD

This report was prepared by Rocketdyne, a Division of North American Aviation, Inc., Canoga Park, California, on Air Force Contract AF04(611)-8515 under Task No. 3850306 of Project No. 3850. "Total Impulse Measuring System for Solid-Propellant Rocket Engine (Research)". Contract AF04(611)-8515 consists of a program for the analysis and design (Phase I), fabrication and testing (Phase II), and installation and testing (Phase III), of an accurate (0.1%) solid-propellant total impulse measurement system for Edwards Air Force Base. This report is submitted to present the development status of the system, and constitutes the Phase II report in the over-all program. It was prepared by the Research Instrumentation Group of the Rocketdyne Research Department.

ABSTRACT

Discussion and results of the two main considerations comprising the intermediate (Phase II) effort are presented: (1) fabrication and test of the component parts of the system prior to their inclusion in the system; and (2) assembly and test of the complete measurement system prior to its delivery to EAFB. Specific results of these separate but related program efforts are, respectively: (1) source inspections and tests, where needed, to determine compliance with Rocketdyne drawings and specifications, and (2) alignment measurements and detailed tests to determine that the overall system performance conformed to the contractual requirement of 0.1% accuracy.

CONTENTS

ILLUSTRATIONS

SUMMARY

The final results of effort in the intermediate (Phase II) portion of the contract was the construction of a total impulse measurement system whose static calibrations to date at Rocketdyne produced a standard deviation of 0.014%, and whose accuracy is directly traceable to dead-weight standards of 0.02% accuracy, at the National Bureau of Standards, Washington, D.C.

All design modifications made during fabrication activities were minor and in no way associated with the measurement method or equipment. Consequently, the quality of the experimental results obtained with the measurement system completely verified the correctness of the approach taken in the analytical and design activities of the Phase I effort.

INTRODUCTION

Air Force Contract AF04(611)-8515, Total Impulse Measuring System for Solid-Propellant Rocket Engines, is a research and development effort comprised of three phases. This report concerns the Phase II effort, fabrication and testing, which was completed prior to the delivery of the measurement system to AFRPL, Edwards Air Force Base, California, on 25 February 1964. It is the third report on the contract (previous Rocketdyne reports: R-5162, Phase I - Analysis and Design; R-5575, Installation and Operation Handbook), and will be followed by a final report which will include the results of tests to be conducted at AFRPL, EAFB.

The following sections compare (1) analytical design goals with fabrication results of all major system components, and (2) the results of empirical static and dynamic calibration tests with the measurement accuracy goal of 0.1%.

SPECIFICATIONS AND TEST RESULTS OF CRITICAL COMPONENTS

CONCRETE ABUTMENT

<u>Specifications</u>

1. Concrete - 4000 psi crushing strength
2. Machining of forward and rear mounting faces
   Each surface flat within 0.001 inch total
   Each surface normal to a common axis within 0.005 inch total
   Surfaces parallel to each other within 0.005 inch total
3. Mounting surface reference holes: $\frac{1}{4}$ inch holes 5.250 inches apart

<u>Measurements</u>

1. Concrete - 5400 psi crushing strength
2. Machining of forward and rear mounting faces
   Forward mounting surface flat within 0.001 inch
   Rear mounting surface flat within 0.0008 inch
   Each surface normal to a common axis within 0.0045 inch
   Surfaces parallel to each other within 0.003 inch
3. Mounting surface reference holes: see Fig. 1

LOAD CELL

<u>Specifications</u> (to be met by test results)

1. Full scale load: 10,000 lbs compression
2. Full scale output: 3 mv/v input (±0.15%)
3. Input volts: 18 VDC
4. Bridge resistance: 350 ohms nominal, each bridge

5. Non-linearity: less than 0.03% full scale

6. Hysteresis: less than 0.02% full scale

7. Repeatability: less than 0.01% full scale

8. Temperature effects:

   a. On zero output: less than 0.15% F.S./100 F

   b. On sensitivity: less than 0.08% of load per 100 F

9. End-plate pilot and mounting holes: see Fig. 2

Additional Specifications (to be met by calculations)

A. Mechanical

1. The transverse stiffness is to be in the order of 1×10^6 (one million) lbs per inch in any direction, assuming the load is supplied at the top of the cell (5 inches from base).

2. The torsional stiffness is to be in the order of 20×10^6 (20 million) pound-inches per radian or less.

3. The bending stiffness for a couple applied to the end of the cell tending to bend the axis of the cell is to be in the order of 25×10^6 (25 million) pound-inches per radian in any direction.

4. The cell response to a 500 lb transverse load is to be a maximum span change of ±0.15% of full scale, and this change increases and decreases sinusoidally as the direction of loading is rotated about the cell.

5. Cell response to torsion is to be negligible within a limit of 1000 pound-inches.

6. A moment of 2500 pound-inches applied at the end of the cell is to have the same effect as item 4

Test Results

1. Capacity: 10,000 lbs
2. Full scale output: 3.0010 mv/v input
3. Input volts: 25 VDC recommended maximum
4. Bridge resistances: 350.2 and 350.3 ohms
5. Non-linearity: 0.01% full scale
6. Hysteresis: 0.003% full scale
7. Repeatability: 0.013% full scale
8. Temperature effects: same as required
9. End plate pilot and mounting holes: as required
10. Response to 500 lb transverse load: ≤ 0.15% full scale
11. Response to 2500 pound-inches moment applied at the end of the cell: ≤ 0.15% full scale

HYDRAULIC CALIBRATOR

Specifications

1. Six calibration points required: 1000, 2000, 4000, 6000, 8000, and 10,000 pound force.
2. Accuracy of each force point: ±0.05%
3. Resolution: 0.02% of full scale
4. Float time of dead-weight gage and force-piston cylinder shall be at least one minute for each calibration point.
5. Hydraulic pump capacity shall be sufficient to provide at least one complete calibration (ascending and descending), including any leakage, without refilling.

6. The dead-weight gage must be capable of being remotely operated.

7. Visual means shall be provided at the control console to indicate when the dead-weight gage is floating and a calibration point may be taken.

8. Weights shall be applied in ascending or descending order selectable through a multi-position switch.

9. The piston cylinder of both the dead-weight gage and force piston cylinder shall be of the same material.

<u>Test Results</u>

All specifications were met and exceeded; specific numerical data as follows:

1. Accuracy of each point: ±0.02%, by reference to the dead weights used at the National Bureau of Standards.

2. Resolution: 0.01 lb at 10,000 lbs (equivalent to one part in 10^6 or 0.0001% FS).

3. Float time of dead-weight gage and force piston exceeds 10 minutes, provided that air is properly excluded from the hydraulic lines.

LOAD CELL POWER SUPPLY

<u>Specifications</u>

1. Type: digitally programmable (decade switching)

2. Input power: 95 - 135 VAC, 60 cycles

3. Output: digitally selectable 0 - 18 VDC, 0 - 200 ma. Two excitation outputs are required.

4. Regulation: 0.01 percent NL-FL and 95-135 VAC

5. Ripple: 0.05 MV rms

6. D.C. isolation: 10 K Meg

7. Stability: 0.005 percent/°C, and ±0.01% in any 8-hour period

8. Noise at bridge (350 ohm): 2 microvolt.

9. Overload protection: fused

10. Overvoltage protection: limits output voltage to 18 VDC.

11. Current regulation: available by jumpering at rear chassis.

12. Size: 3½" x 19" x 10" for rack mounting

Test Results

All specifications were met or exceeded, with the minor exception given as follows:

1. Stability: 0.007 percent/°C

BRIDGE BALANCES

Specifications

1. Type: decade switching of precision voltage dividers connected in a Kelvin-Varley arrangement.

2. Input: 3 wires to strain-gage bridge

3. Resolution: balance to one microvolt with 350 ohm bridge

4. Size: 3½" x 19" x 6" for rack mounting

5. General: six front panel mounted controls to allow nulling with bridge unbalances of ±5%. Precision tolerance resistors of long term stability are to be used throughout. Quality switches of low contact resistance are to be used in order to assure excellent repeatability. Terminals are to be provided for a limiting resistor if desired. All switch positions in each decade are to be numbered to enable repeatable settings.

Test Results (see Fig. 3)

INTEGRATING DIGITAL VOLTMETER

Specifications (quoted by Dymec Div. of Hewlett Packard)

A. D.C. voltage measurements

1. Noise rejection: overall common mode 140 db at all frequencies

2. Accuracy specifications for ±10% line voltage change
   Stability (at constant temp): ±0.03% of full scale (0.1 volt range)
   Linearity: ±0.005% of full scale (zero to full scale)
   Temperature effects: (+10 C to +50 C)
   a. Scale faster: +0.002% of reading per°C
   b. Zero ±0.002% of full scale per°C (0.1 volt range)
   c. Internal calibration source: +0.002% per°C

B. D.C. voltage integration
   Accuracy same as for D.C. voltage measurement, with exception that errors given as percent of full scale must be multiplied by the integration time in seconds.

Test Results

Laboratory tests, at the Rocketdyne Research Instrumentation Laboratory, of the integration capability of the Dymec 2401A integrating digital voltmeter, show correlation, within 0.02%, of theoretical input and measured values of area with pulses 1 volt high, pulse rise/fall times of faster than 500 microseconds, and durations in the range 20 to 200 milliseconds.

OPTICAL ALIGNMENT OF TEST STAND

Photo 1 shows the configuration of tooling telescopes and scales used for the vertical and horizontal alignment of the load cell and calibrating piston. Figure 1 shows the alignment of the two mounting faces of the concrete abutment. Constructional alignment of the load cell and calibrating piston was achieved through the accurate machining of the center holes in each mounting surface and of the load cell assembly mated to the forward surface. Installational alignment of the calibrating piston crossbar was accomplished by reference to the machined edge of the abutment base plate and to the mounting face center holes of the leveled abutment. The end results of alignment efforts were as follows:

	Elevation (Distance from arbitrary horizontal reference line) inches	Lateral (Distance from reference edge of base) inches
Crossbar centerline	20.127	28.132
Rear face centerline	20.125	28.127
Front face centerline	20.125	28.128

Consequently, elevation alignment is within 0.002 inch and lateral alignment within 0.005 inch.

MEASUREMENT SYSTEM ELECTRONIC FABRICATION

The electrical assembly of all measurement components of the system is shown in Fig. 4 and in the block diagram of Fig. 5. Electrical tests of the system, exclusive of calibrations, consisted of electrical zero stability and noise tests. Zero stability test results are typified in Fig. 3. Electrical noise at no time was a problem at Rocketdyne, as observed by the Dymec integrating digital voltmeter.

STATIC CALIBRATIONS OF ENTIRE SYSTEM

A series of complete static calibrations was performed on the entire system over a period of eight calendar days. The calibrations were in accordance with the Operation and Maintenance Manual, R-5575. Four successive calibration were performed on each of four successive days, followed by one day of no calibrations and then three more days with four calibrations each. On alternate days the ambient air temperature of the test area was in the normal room temperature range (68 - 73 F) and in a somewhat cooler range (60 - 64 F). The test data were statistically analyzed by the Mathematics and Statistics Group of the Rocketdyne Research Department to determine the linearity and precision variational properties. The instantaneous (short term) variational properties of the system were studied as well as the long term variational or "drift" properties of the measuring system.

A full description of the tests and procedures including pertinent tabulated data is presented in the Appendix. Although both outputs (A gage and B gage) of the load cell were monitored, they were so similar that only the B gage data were analyzed.

Not all of the data from test sequences 2 <u>through</u> 8 were actually used in the final analysis. All of the data from sequences <u>2</u> and <u>8</u> were used, but, for sequences 3 through 7, the 1, 4, 8, 8, 4, and 1 points from cycles 1 and 4 were used. For sequences 2, 4, and 6, the 2 and 2 points from cycle 2 and the 6, 10, and 6 points from cycle 3 were used. For sequences 3 and 5, the points used were: the 2, 10, and 2 points from cycle 2, and the 6 and 6 points from cycle 3. Thus, a 184 point sample of the tabulated 308 points was analyzed.

Each cycle was divided into an "up-half" (0,1,2,4,6,8, and 10) and a "down-half" (8,6,4,2,1, and 0). The zero-reading for each half of the data was subtracted from each of the other readings in that half of the cycle. The model used for regression was:

For up data:

$$(y-0)/xV_0 = A+B(\text{if up}) + CxT+Dx(\text{if up})$$
$$+ Ex^2(\text{if up}) + F(V_0-17.990) + \epsilon$$

For down data:

$$(y-0)/xV_0 \quad A+CxT + F(V_0-17.990) + \epsilon$$

where

- x denotes force (thousands of pounds)
- T denotes ambient temperature (F)
- V_0 denotes bridge voltage (volts), and
- y denotes the load cell system output (millivolts)
- ϵ denotes random error involved in each measurement

Many additional terms were tried, including the cycle number (a test for short term drift) and for extended time (a test for long term drift), but they were not significant and were therefore discarded.

Only one term in the above expression is unexpected, and that is the term in V_0. It was thought that V_0 variations (0.005 about 17.990), although small, would be sufficiently corrected by dividing the load cell output by V_0, but this apparently is not the case.

The standard deviation of residuals was estimated to be $\hat{\sigma} = 0.000043$, and since the average value of the expression is 0.2984, this represents an estimated coefficient of variation of 0.0144%, a rather low figure. The worst points were in sequence 2 at the beginning of cycle 3 and at the end of cycle 4, and in sequence 3 at the beginning of cycle 1. They deviated roughly 4, 6, and 4 standard deviations, respectively, from the above regression.

The estimates of the parameters are

$$\hat{A} = .298,667$$

$$\hat{B} = -.000,462$$

$$\hat{C} = -.000,---,592$$

$$\hat{D} = .000,088,2$$

$$\hat{E} = -.000,003,867$$

$$\hat{F} = -.004,76$$

Since a calibration curve must be used for both up and down data, we substitute 0.5 in each term with the notation "if up", giving

$$(y-0)/xV_0 = (.298,436) - (.000,000,59)\,xT + (.000,044)\,x - (.000,001,93)x^2 - (.004,76)(V_0 - 17.990) + \epsilon + \Delta$$

The hysteresis bias term in the regression is

$$\Delta = \pm \tfrac{1}{2}\left[B + Dx + Ex^2 \right]$$

and therefore the hysteresis error in $(y-0)/V_0$ is $\pm\, x\Delta$. This is maximized when

$$3Ex^2 + 2Dx + B = 0,$$

for which the solution is

$$x = \frac{-D + \sqrt{D^2 - 3BE}}{3E}$$

$$= 3.36$$

$$\pm\, x\Delta = +\, 1.68\left[B + Dx + Ex^2\right] \cong \pm\, .000353$$

Now $(y-0)/V_0$ at full scale is roughly 2.984, and therefore the maximum hysteresis error as a percentage of full scale is .012%.

The overall linearity can most easily be tested <u>non statistically</u> by examining the up data directly. By using the 10,000 lb point to represent the slope determining point, a value for the calibration constant (K_c) in volts per lb can be determined.

$$(y-y_o)/x = K_c = \frac{\text{millivolts (at 10,000 lbs)}}{\text{10,000 lbs}}$$

Examining all of the B gage up data on this basis and comparing K_c with the corresponding value at 1000 lb yields the following conclusion:

The worst case error observed is in test sequence number 2, cycle number 4 where the error is $\frac{0.0035 \times 100}{5.364} = 0.066\%$. The typical error for sequences 4 through 8 is about $\frac{0.001 \times 100}{5.365} \approxeq 0.02\%$ of actual value.

Statistically, all of the data can be considered to have demonstrated a singular calibration factor of (0.298,407 ± a Standard Deviation of 0.000,127,505) or (0.298,407) millivolts per volt excitation per thousand pounds ±0.08% at the 95% confidence level (2σ). Alternately, the data demonstrated that it agrees with equation (2) ±0.03% at the 95% confidence level ±0.012% due to hysteresis.

The system demonstrated no significant short term or long term drift.

DYNAMIC TESTING

Description of Technique and Apparatus

Early in the Phase I effort it was determined that an elastic-collision or impulse type of dynamic calibration would involve unnecessary expense and extremely large and, possibly, destructive forces. Therefore, this was discarded in favor of a "step-unloading" of force produced by a break-link. This technique can best be described as follows:

1. A force was gradually applied to the test stand through the "break-link" which was fabricated to fracture at approximately 5000 lbs of force. The force was applied by means of a manually operated hydraulic jack and a mechanical lever (Fig. 6).
2. The electrical circuit including the automatic gating circuit, is depicted in Fig. 7. On-line integration of the load cell's response to the step excitation was accomplished by means of two Dymec Digital Integrating Voltmeters - one connected to integrate the positive signal and the other to integrate the negative signal. This latter is necessary because the load cell was resonated at the zero force level. Total impulse is obtained by subtracting the negative value from the the positive value. This empirically derived value was then compared with the theoretically calculated value of the step's impulse.
3. The output of the load cell bridge was simultaneously recorded on tape to provide natural frequency and dynamic linearity information. Figure 8 is a reproduction of the actual record of the load cell output.

Results

Theoretical Calculated Total Impulse.

$$\text{Given: } \frac{650 \text{ lbs}}{g} = \text{dynamic mass of test stand} = m$$

$$24 \times 10^6 \text{ lbs/ft} = \text{load cells spring constant} = k$$

$$5152 \text{ lbs} = \text{fracture force} = F$$

$$\frac{5152}{24 \times 10^6} \text{ ft} = \text{displacement} = x$$

$$F = kx \text{ with } \dot{x} = 0 \text{ at instant of fracture}$$

$$\text{Energy} = \int_0^x F dx = k \int_0^x x dx = \underbrace{\tfrac{1}{2} k x^2}_{P.E} = \underbrace{\tfrac{1}{2} m v^2}_{K.E.}$$

$$\text{and } V = \sqrt{\frac{k x^2}{m}}$$

$$\text{Impulse} = I = mv = m \sqrt{\frac{k x^2}{m}} = x \sqrt{km}$$

$$I = \frac{5152}{24 \times 10^6} \sqrt{24 \times 10^6 (20.2)} = 4.77 \text{ lb-sec}$$

The empirically measured impulse was 5.2 lb-sec. The two values compare very well considering that: (1) the ±1 count ambiguity of the digital integrating voltmeter represents ±0.2 lb-sec of impulse and (2) the difference between the two values is small compared with the total range of the measurement system (1500 lb-sec to 100,000 lb-sec).

Frequency Response Characteristic. As can be observed from Fig. 8, the system can be described as a linear, second-order system, having two degrees of freedom. The fundamental resonance of 172 cps agrees well with the mathematical model established during the Phase I effort (175 cps). Also the model provided for two degrees of freedom.

A rather surprising aspect of the response function, however, was the relative amplitude of the second resonance (modulation envelope), and the apparent low damping factor associated with it.

It is apparent that Fig.8 represents an interference pattern and therefore the abutment must be resonating at the second frequency, 17 cps either above or below the fundamental of 172 cps.

Further experimental investigation of this phenomenon was delayed until the demonstration testing phase (Phase II) at AFRPL for two reasons: (1) The on-line dynamic calibration demonstrated that no significant errors were caused by this second degree of freedom, and (2) the experiment at Rocketdyne was performed without the test stand being bolted or secured firmly to earth, whereas the testing phase at AFRPL will be accomplished with the test stand securely affixed to a concrete dead-man and earth.

It is felt that by providing an effectively lower mechanical impedance coupling to earth, the second degree of freedom will be minimized.

~~17~~

1/2 FRAMES

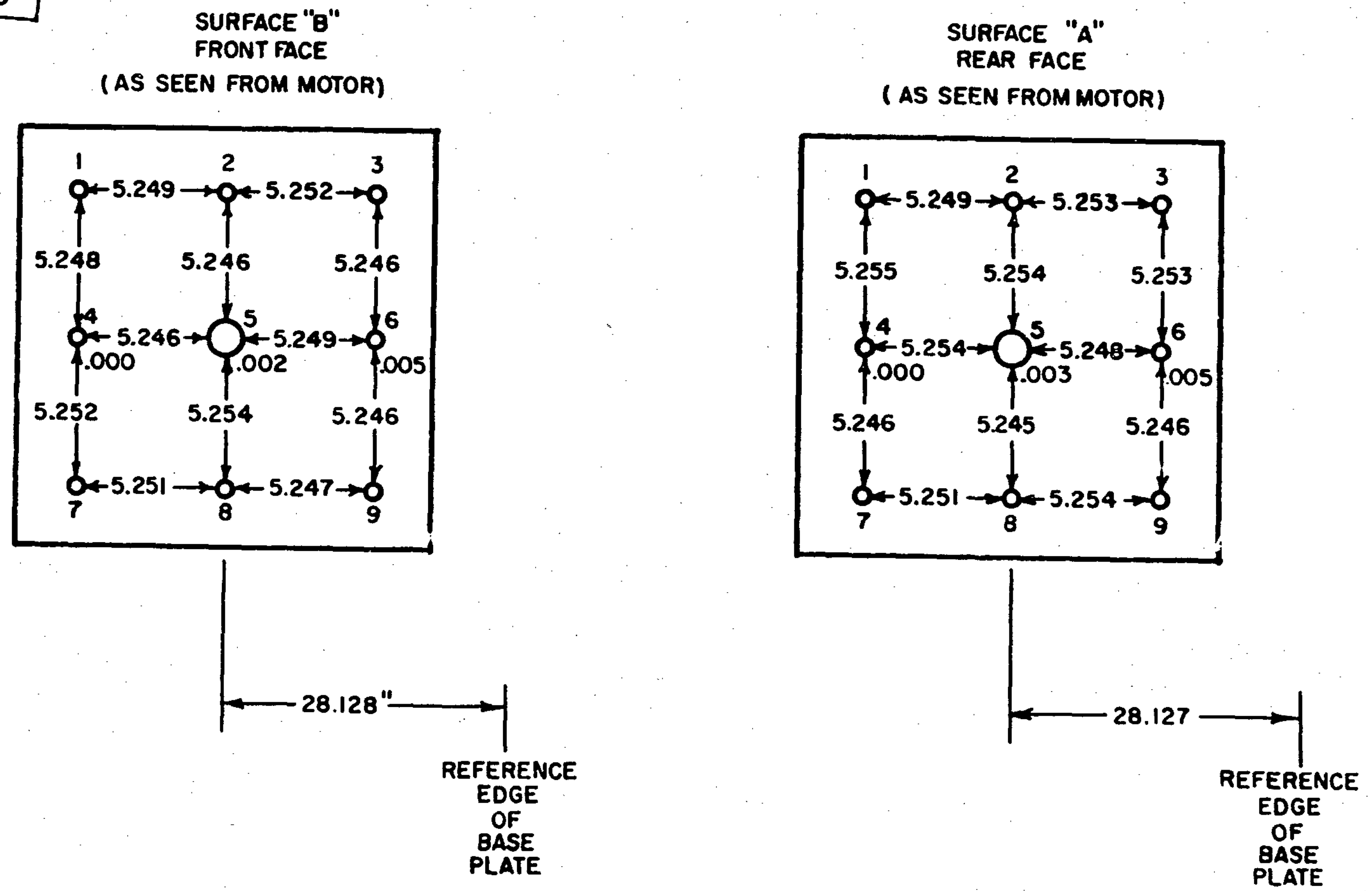
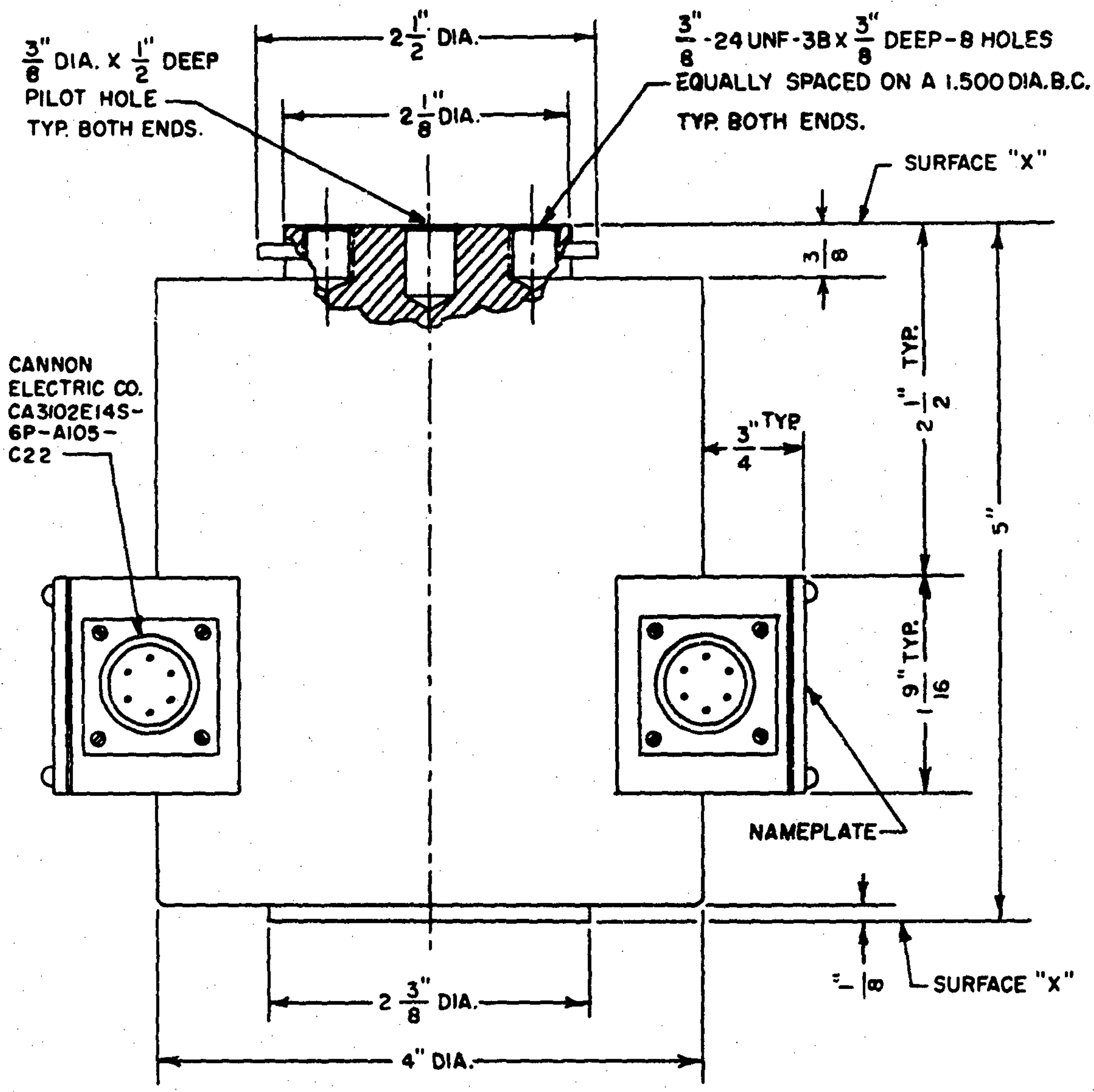


Figure 1. Abutment Mounting Face Reference Holes



GENERAL NOTES

1. BEARING SURFACES "X" ARE LAPPED AND ELECTROPLATED WITH LEAD .001/.002 THK.

Fig. 2. Dimensional Drawing of Load Cell

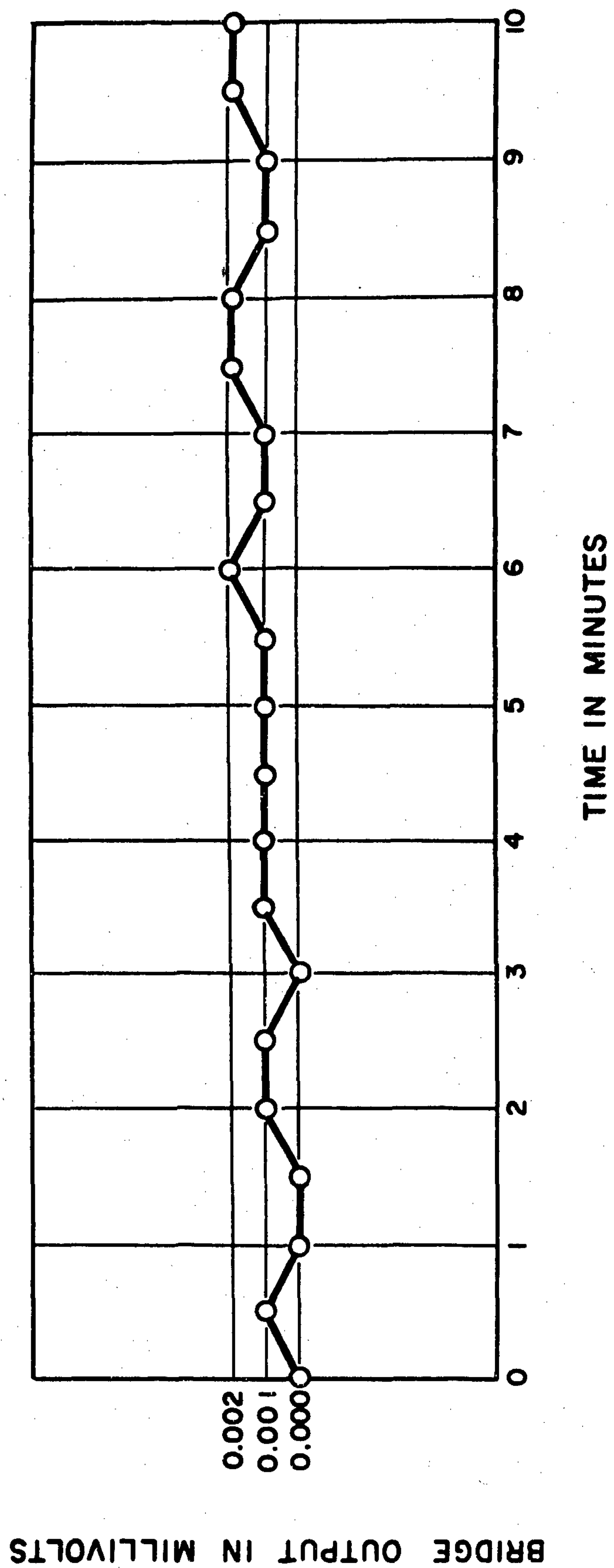


Figure 3. Zero Drift of Entire Measurement System

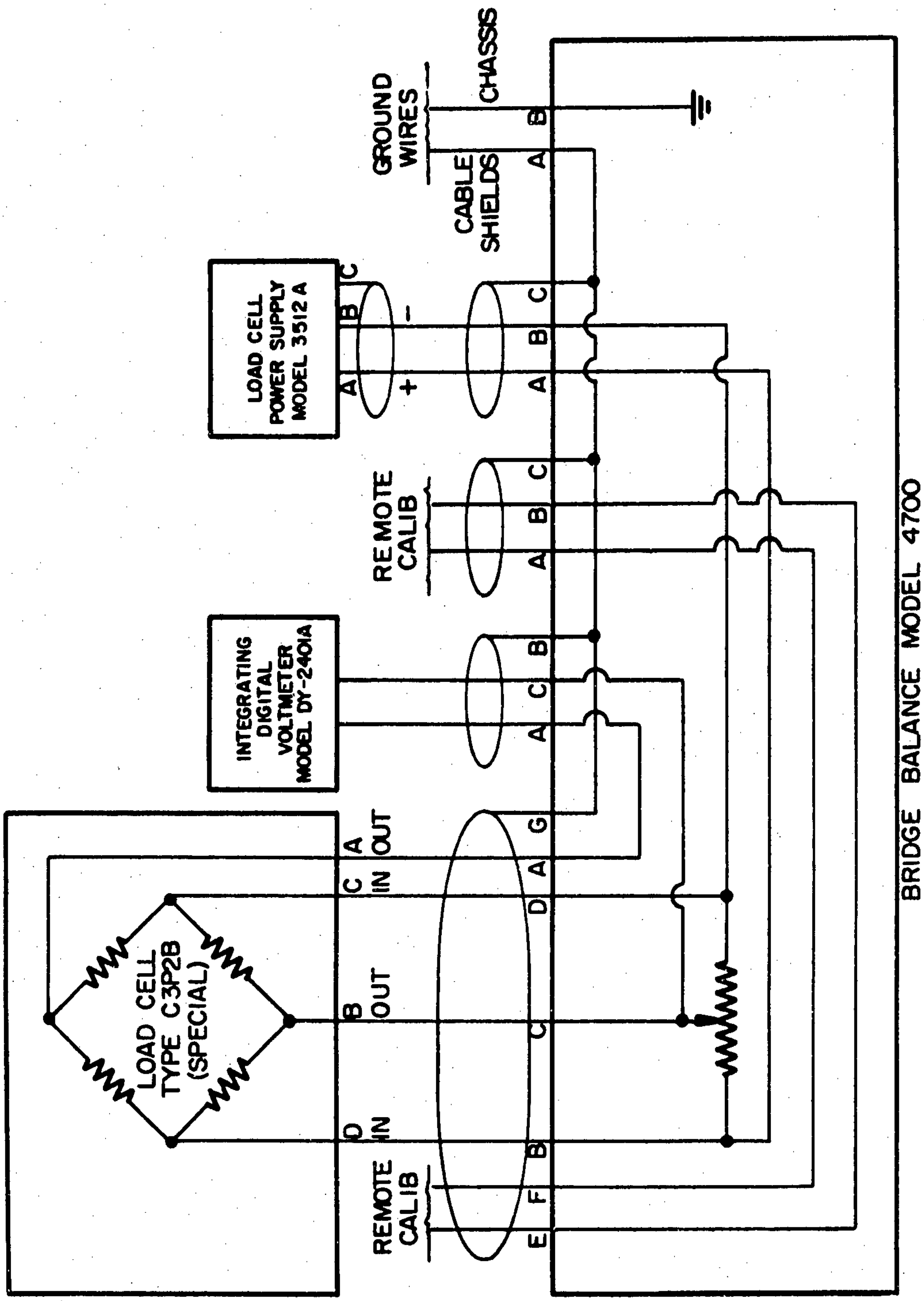


Fig. 4. Block-Schematic Diagram of Measurement Circuitry

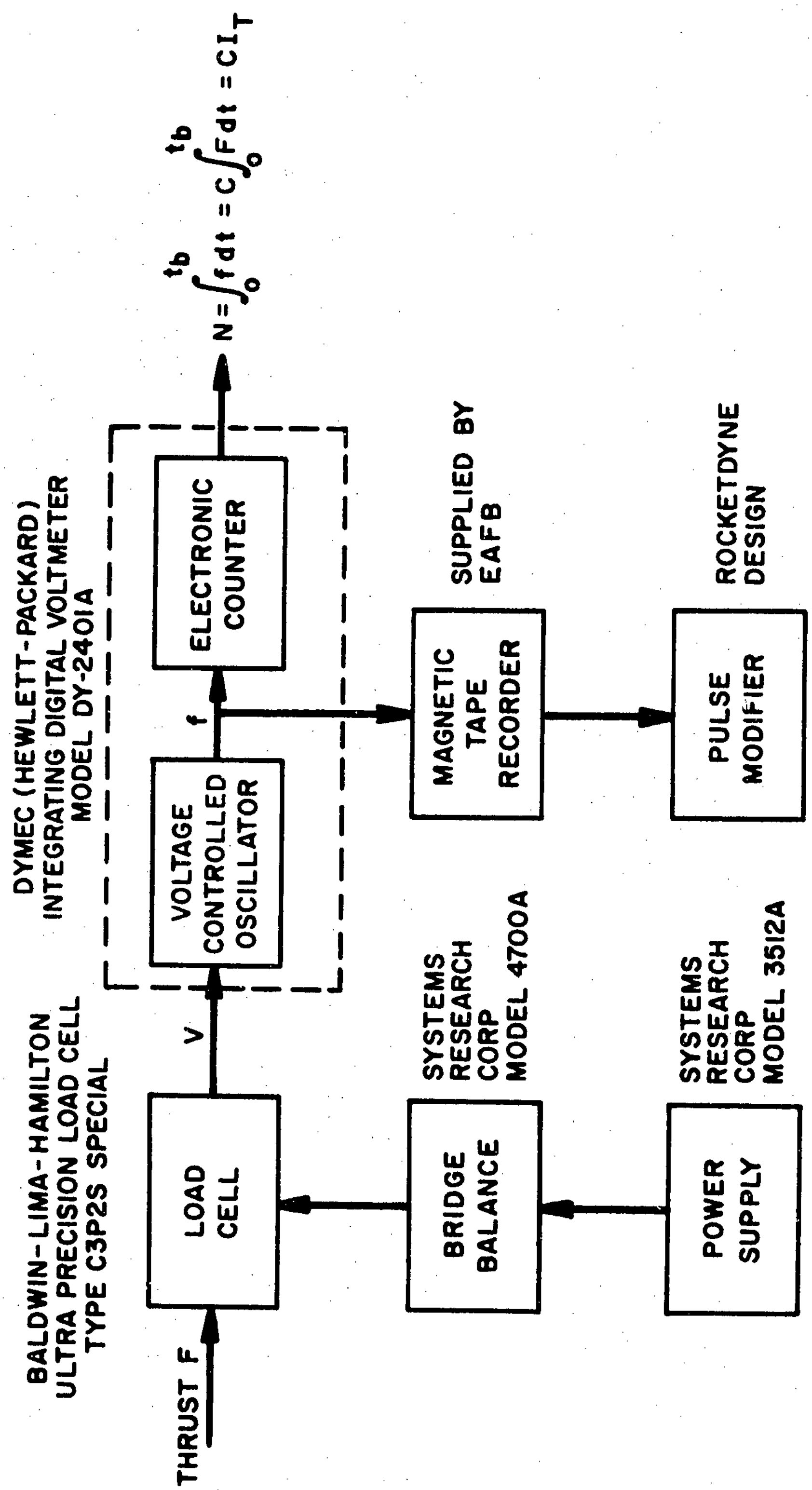


Figure 5. Block Diagram of Measurement System

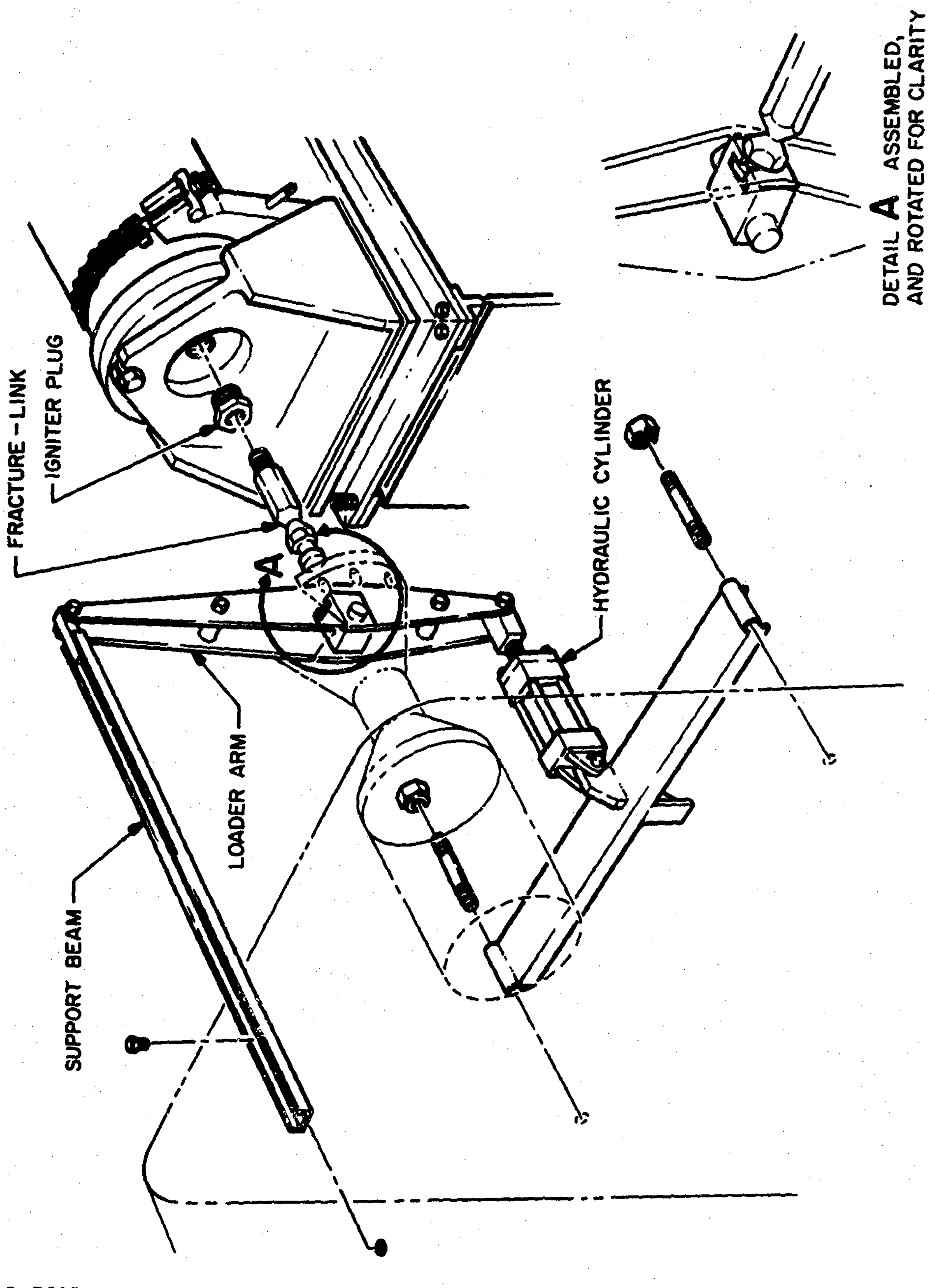


Figure 6. Dynamic Test Setup (mechanical)

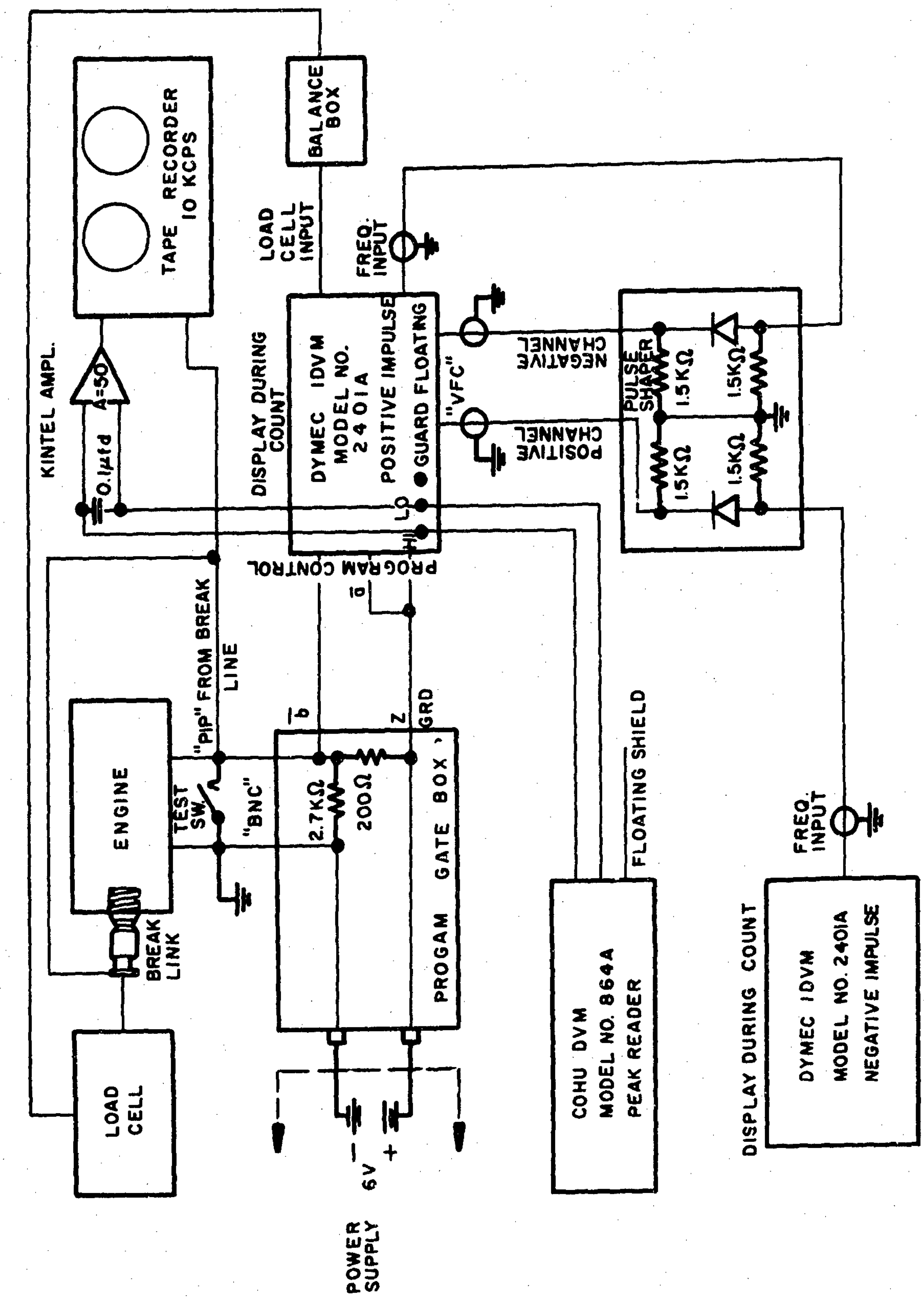


Figure 7. Dynamic Test Setup (electrical)

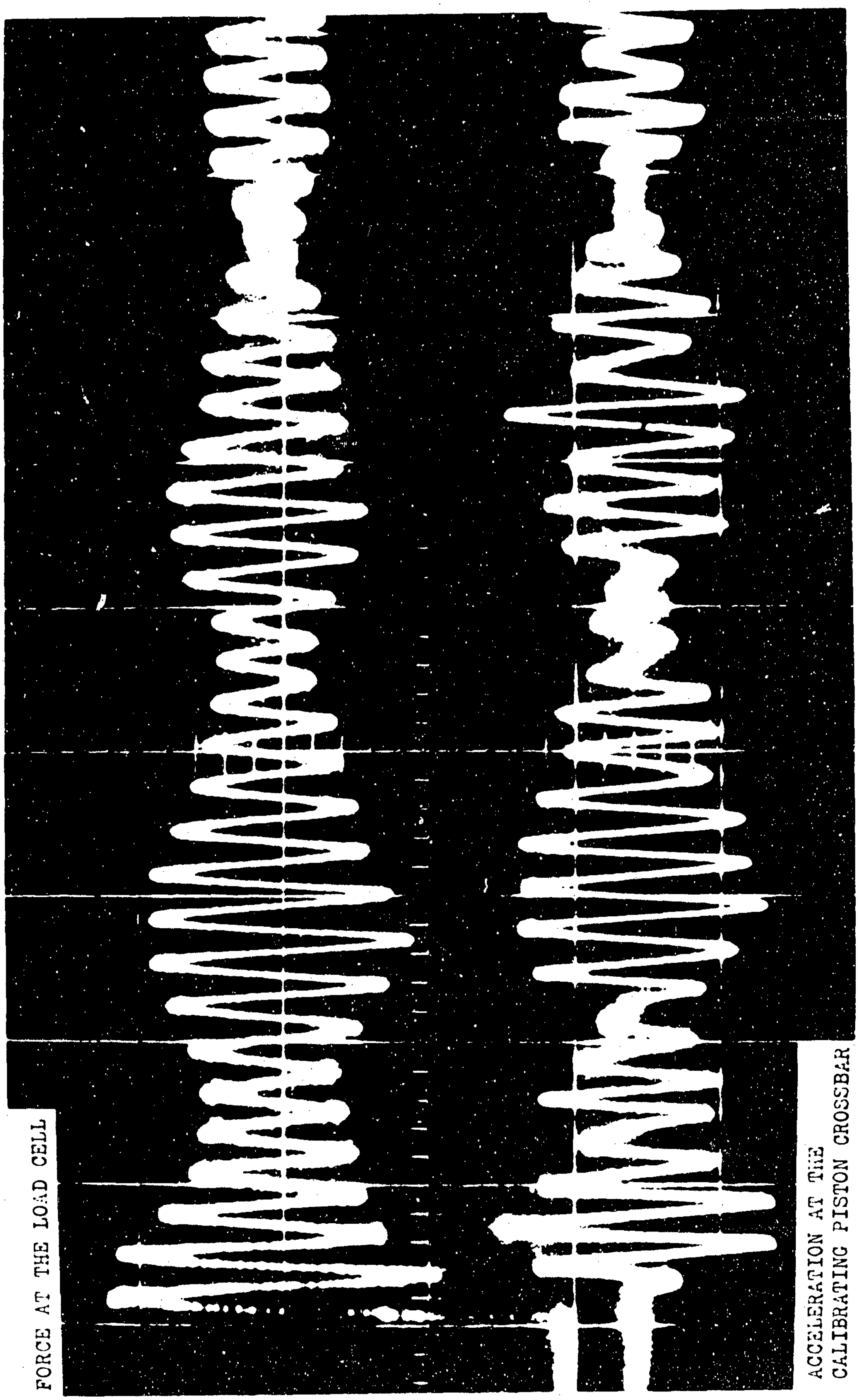


Figure 8. Oscillogram of System Response to Step Unloading

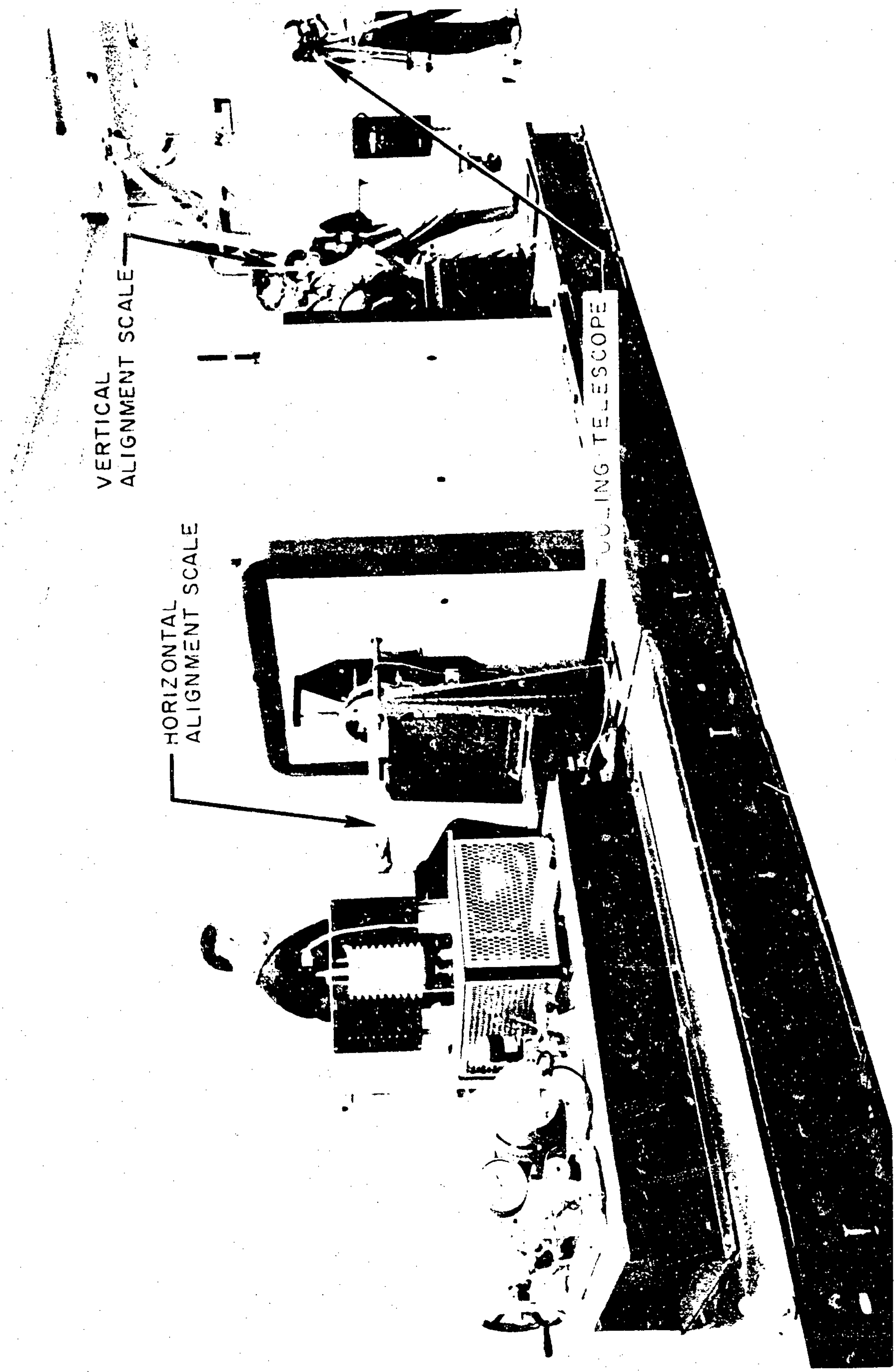


Photo 1. Alignment of Calibrator and Load Cell

APPENDIX

STATIC CALIBRATION TEST SERIES

TOTAL IMPULSE MEASURING SYSTEM FOR SOLID ROCKET ENGINE

G.O. 8412

OBJECT

This was a special series of static calibrations conducted to provide the necessary data to evaluate the precision characteristics of the Total Impulse Measuring System. The data generated was used by the Mathematics and Statistics Group (D/591-351) to determine the linearity and precision variational properties. The instantaneous (short term) variational properties of the system was studied as well as the long term variational or "drift" properties of the measuring system.

The test series is composed of eight "daily test sequences" for ten days skipping the week-end day of Sunday. Each daily test sequence was composed of 4 calibration test cycles of 0, 1, 2, 4, 6, 8, 10, 8, 6, 4, 2, 1, 0 kilopound steps noting the system signal output for each force increment. On alternate days the daily test sequence wasmade at a lower than normal ambient temperature (low temperature one day; normal the next day, etc.).

The parameters noted were: Date, ambient temperature, humidity, barometric pressure, range or span settings (strain gage power supply), balance settings, time at the start and finish of each calibration test cycle of the daily test sequence, applied calibration force, and the system output voltage as measured using the system Dymec Integrating Digital Voltmeter.

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TEST PROCEDURE

PRE-TEST

1. Turn the equipment on
2. Vent the Ruska calibrator by depressing execute button with force selector switch at zero pounds.
3. Record the time of day the equipment was turned on.
4. After a $1\frac{1}{2}$ hour warmup start the pre-test.
   a. Record time of day, ambient temperature, barometric pressure, and relative humidity.
   b. Vent the Ruska calibrator as above.
   c. Re-zero and calibrate the Dymec integrating digital voltmeter (DIDVM) model No. 2401A.
   d. Check load cell strain gage power supply voltage and setting (span or range).
   e. Set the load cell strain gage balance unit for zero signal output.
   f. Record d and e.
   g. Exercise the Ruska calibrator by pushing the execute switch with the force selector at 1000 pounds and after the "Ruska" cycle is complete return the force selector to 0 pounds and execute again.
   h. Repeat items c and e and record the final bridge balance unit setting.

DAILY TEST SEQUENCE

Data recording of the daily test sequence is to be accomplished after the pre-test is completed, as follows:

1. Record the time, ambient temperature, and bridge balance unit setting at the beginning of the calibration test cycle (force = 0 pounds).

2. Record the calibration test cycle (0, 1, 2, 4, 6, 8, 10, 8, 6, 4, 2, 1, 0).

3. Record the time and ambient temperature at the end of the calibration cycle (force = 0 pounds).

4. Rebalance the bridge balance unit for the next calibration cycle.

5. Repeat 1 through 4 for a total of 4 to 5 calibration test cycles with a minimum of delay between cycles.

The accumulated data is presented in tabular form on the following pages. The first table (Test Sequence Number Two) demonstrates the format which is followed on the subsequent tabulations.

Table 1. Static Calibration Test Data

Test Sequence Number		First			
Date		2-5-64			
Relative Humidity (%)		42			
Barometric Pressure (inches Hg)		28.060			
Test Cycle Number		One	Two	Three	Four
Time of Day		7:35	7:50	8:10	8:30
Temperature (Degrees Farenheit)		59	59.5	60	61
Bridge Voltage (Millivolts)		17995	17994	17993	17991
Strut Stage	Force (Thousands of Pounds)	Load Cell System Output in Microvolts			
A	0	00000	00001	00001	00000
	1	05366	05366	05364	05363
	2	10735	10734	10733	10731
	4	21472	21472	21470	21467
	6	32210	32207	32205	32201
	8	42944	42940	42938	42932
	10	53677	53672	53669	53662
	8	42949	42944	42942	42937
	6	32217	32215	32212	32206
	4	21485	21480	21479	21475
	2	10746	10745	10743	10740
	1	05375	05374	05372	05369
	0	00001	00001	00000	00002
B	0	00001	00001	00002	00000
	1	05366	05366	05365	05364
	2	10736	10736	10735	10732
	4	21476	21475	21474	21471
	6	32216	32214	32211	32207
	8	42953	42950	42947	42941
	10	53688	53685	53681	53675
	8	42959	42955	42952	42947
	6	32225	32222	32220	32214
	4	21489	21486	21484	21480
	2	10748	10747	10745	10742
	1	05375	05375	05373	05371
	0	00001	00001	00000	00003

Table 2. Static Calibration Test Data

Test Sequence Number		Three			
Date		2-6-64			
Relative Humidity (%)		7			
Barometric Pressure (inches Hg)		28.100			
Test Cycle Number		One	Two	Three	Four
Time of Day		10:30	11:00	11:25	11:43
Temperature (Degrees Farenheight)		72	72	73	73
Bridge Voltage (Millivolts)		17984	17984	17984	17983
Strain Gage	Force (Thousands of Pounds)	Load Cell System Output in Microvolts			
A	0	00000	00000	00000	00001
	1	05364	05363	05365	05366
	2	10728	10728	10729	10730
	4	21460	21459	21459	21459
	6	32190	32189	32188	32189
	8	42919	42916	42917	42915
	10	53646	53643	53642	53641
	8	42924	42922	42921	42919
	6	32199	32198	32198	32196
	4	21422	21470	21471	21470
	2	10741	10740	10741	10740
	1	05373	05372	05372	05372
	0	00001	00001	00001	00002
B	0	00001	00001	00000	00001
	1	05362	05363	05365	05367
	2	10728	10729	10731	10732
	4	21461	21463	21463	21464
	6	32193	32194	32195	32195
	8	42924	42924	42926	42924
	10	53654	53653	53653	53651
	8	42931	42931	42930	42929
	6	32204	32204	32205	32203
	4	21475	21475	21476	21475
	2	10742	10743	10743	10744
	1	05372	05374	05374	05373
	0	00001	00002	00003	00002

Table 3. Static Calibration Test Data

		Four 2-7-64 13 28.185			
		One 8:40 60.5 17993	Two 9:02 61.5 17993	Three 9:27 62 17991	Four 9:47 63 17989
A	0	00000	00001	00001	00001
	1	05366	05368	05367	05367
	2	10734	10735	10735	10733
	4	21470	21472	21469	21468
	6	32205	32207	32202	32199
	8	42939	42938	42932	42929
	10	53670	53669	53662	53658
	8	42944	42943	42937	42934
	6	32215	32213	32209	32207
	4	21483	21481	21479	21477
	2	10747	10747	10745	10745
	1	05376	05376	05375	05375
	0	00003	00003	00003	00003
B	0	00000	00001	00000	00000
	1	05367	05368	05367	05368
	2	10736	10737	10736	10735
	4	21475	21476	21473	21472
	6	32213	32214	32208	32206
	8	42949	42948	42943	42939
	10	53684	53682	53674	53670
	8	42956	42954	42947	42943
	6	32223	32221	32217	32215
	4	21488	21487	21484	21482
	2	10750	10749	10748	10747
	1	05378	05377	05375	05375
	0	00003	00003	00003	00002

Table 4. Static Calibration Test Data

		Five 2-8-64 20 28.160			
		One 7:30 68 17987	Two 7:48 69 17987	Three 8:07 69 17986	Four 8:28 69 17985
A	0	00000	00001	00001	00000
	1	05364	05364	05364	05363
	2	10730	10730	10731	10729
	4	21462	21462	21463	21461
	6	32194	32193	32194	32190
	8	42924	42922	42923	42919
	10	53652	53649	53649	53645
	8	42928	42925	42927	42923
	6	32203	32201	32202	32200
	4	21473	21473	21474	21471
	2	10741	10742	10744	10741
	1	05372	05373	05375	05372
	0	00002	00003	00004	00003
B	0	00000	00000	00002	00000
	1	05365	05366	05366	05364
	2	10732	10733	10733	10731
	4	21466	21466	21468	21463
	6	32200	32199	32199	32195
	8	42931	42930	42931	42925
	10	53662	53659	53659	53653
	8	42936	42935	42936	42931
	6	32209	32208	32207	32205
	4	21479	21478	21479	21475
	2	10744	10745	10746	10743
	1	05375	05376	05377	05374
	0	00003	00003	00004	00002

Table 5. Static Calibration Test Data

		Six 2-10-64 29 28.050			
		One 7:45 64 17987	Two 8:00 64 17987	Three 8:17 64 17987	Four 8:33 64 17987
A	0	00000	00001	00001	00000
	1	05364	05365	05365	05364
	2	10729	10732	10731	10729
	4	21463	21463	21463	21461
	6	32194	32195	32194	32192
	8	42923	42925	42922	42919
	10	53651	53652	53649	53646
	8	42928	42929	42927	42924
	6	32202	32203	32201	32199
	4	21474	21475	21473	21471
	2	10742	10743	10741	10740
	1	05374	05374	05372	05371
	0	00003	00003	00003	00002
B	0	00000	00000	00001	00000
	1	05365	05367	05367	05365
	2	10732	10733	10733	10732
	4	21467	21469	21468	21466
	6	32202	32203	32203	32201
	8	42934	42936	42934	42932
	10	53665	53667	53665	53661
	8	42940	42942	42939	42937
	6	32211	32212	32211	32209
	4	21480	21481	21479	21477
	2	10745	10746	10745	10744
	1	05375	05376	05375	05373
	0	00003	00003	00003	00002

Table 6. Static Calibration Test Data

		Seven 2-11-64 40 27.875			
		One 8:12 71 17985	Two 8:30 73 17985	Three 8:45 75 17984	Four 9:01 75 17983
A	0	00000	00000	00000	00000
	1	05362	05361	05362	05362
	2	10727	10727	10727	10728
	4	21458	21458	21458	21457
	6	32189	32187	32186	32185
	8	42916	42915	42913	42916
	10	53643	63640	53638	53636
	8	42921	42919	42918	42916
	6	32195	32195	32195	32194
	4	21468	21468	21469	21468
	2	10737	10738	10740	10739
	1	05369	05370	05373	05373
	0	00001	00001	00003	00002
B	0	00000	00000	00000	00000
	1	05365	05363	05364	05364
	2	10731	10729	10730	10730
	4	21463	21461	21462	21462
	6	32197	32194	32193	32192
	8	42926	42924	42922	42920
	10	53655	53652	53650	53647
	8	42931	42929	42927	42926
	6	32203	32202	32202	32200
	4	21474	21474	21474	21474
	2	10740	10740	10743	10742
	1	05372	05371	05374	05374
	0	00001	00002	00003	00003

Table 7. Static Calibration Test Data

		Eight 2-12-64 10 28.115			
		One 7:30 61 17995	Two 7:47 61 17995	Three 8:00 62 17995	Four 8:12 62 17994
A	0	00000	00000	00001	00001
	1	05364	05366	05366	05366
	2	10734	10736	10734	10734
	4	21471	21472	21471	21470
	6	32207	32208	32206	32205
	8	42941	42941	42938	42936
	10	53673	53673	53670	53666
	8	42946	42945	42944	42940
	6	32216	32215	32212	32212
	4	21483	21482	21481	21480
	2	10746	10746	10745	10744
	1	05375	05375	05375	05375
	0	00003	00003	00003	00003
B	0	00000	00000	00000	00000
	1	05367	05367	05367	05366
	2	10736	10736	10736	10736
	4	21475	21475	21474	21473
	6	32213	32212	32212	32210
	8	42947	42947	42946	42944
	10	53681	53682	53679	53676
	8	42954	42953	42952	42948
	6	32223	32222	32220	32218
	4	21487	21486	21484	21483
	2	10748	10748	10747	10746
	1	05376	05376	05375	05375
	0	00002	00002	00002	00001

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